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MONTHLY PROGRESS REPORT

FOR

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INDOOR ENVIRONMENT DEPARTMENT

Environmental Energy Technologies Division
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Notice

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1. Energy Performance of Buildings

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A. Infiltration, Ventilation, Indoor Air Quality
Sponsor(s): DOE-EE
Collaborator(s): University of Alberta

Background

Using between 2-4 Quads of energy, infiltration is a major energy expense in existing envelope-dominated buildings. Much of this project is devoted to the characterization and optimization of infiltration in small buildings. Model development, instrumentation design, test methods, analysis and stock characterization are all continuing pieces of the work in this area. Understanding the impacts of infiltration and ventilation for both energy and indoor air quality is done through modeling and measurement. Combined heat and mass transport modeling (e.g. in the infiltration heat recovery project) is necessary to accurately determine energy use and potential retrofits.

In new construction, infiltration is much less and does not normally provide sufficient ventilation for acceptable indoor air quality. Accordingly this project supports ventilation standards through scientific research and also participation in consensus standards and code support. Max Sherman is chair of ASHRAE's Residential Ventilation standard (62.2P) and also serves on the non-residential standard. Data collection and analysis of air tightness of new construction is currently in progress.

Technology transfer and implementation support activities to state, federal, and international groups is a continuing effort. LBNL represents the US at Annex V of the IEA/ECBCS project, the Air Infiltration Centre. LBNL staff strongly support ASHRAE, ASTM and other consensus activities as well as assisting others in program and code development. Scientific and popular articles are also used to assist users in making use of DOE-funded research.

January 2001

A frank and open meeting of SPC 62.2 (Residential Ventilation standard) was held at the ASHRAE Winter meeting in Atlanta. After reviewing all the comments and making modifications, the committee recommended that the revised standard go for its second full public review. This action was not accepted by the Board Policy Committee on Standards, which believes more progress towards achieving consensus is necessary.

M. Sherman and I. Walker completed an LBL report on Infiltration Heat Recovery and sent the paper for consideration at the Buildings VIII conference to be held in December.

LBNL is developing the Residential Diagnostics Database , which includes envelope air tightness, duct leakage, and house characteristics. Like previous studies we have conducted, the data collected will be used to evaluate national trends in the air-tightness and energy efficiency of new houses.

We have solicited data from a wide range of individuals and organizations, based on information obtained from Home Energy Rating (HERS) organizations, blower door manufacturers, state energy office contacts and other organizational lists. Individuals and organizations were contacted via e-mail and phone. Notices describing the Database and asking for data were placed in the May/June Home Energy Magazine and the June Energy Conservatory newsletter. A number of organizations have responded to this request.

Twenty-six datasets have been received. Of these, twenty-two datasets have sufficient data to be included in the database. The following datasets represent 13,479 houses that have sufficient air tightness and house characteristic data. The houses in the database have an average floor area of 2,207 square feet (std. dev. = 1073.2).

The Residential Diagnostics Database currently represents 27 U.S. states and includes a total of 13,479 observations. A handful of larger (non-residential) buildings and a number of apartments and townhouses have been submitted by respondents, but are not included in this count. At least 34% of the observations are identified as "energy-efficiency program" houses, which is much higher than current building practices.

At this time there are 12,847 envelope air tightness measurements and 9,836 duct leakage measurements. The data sources may report the year built, the date that the house is tested, or no date information. On a first cut, we looked at reported year built to determine age. "Year Built" is reported for 74% of the houses. Of these, 71% have been built since 1990. We will use the test date and other information into account in order to approximate year built for the rest of the database.

Work on the analysis of this data will continue into the summer. A technical report is anticipated by the end of the fiscal year.

B. Residential Envelopes and Commissioning

PIER Residential Commissioning Project
Sponsor(s): DOE, California Energy Commission (CEC)
Collaborator(s): None

<u>Background</u>

Currently, houses do not perform optimally or even as many codes and forecasts predict, largely because they are field assembled and there is no consistent process to identify deficiencies or to correct them. As a step toward alleviating this problem, the Public Interest Energy Research (PIER) program of the California Energy Commission (CEC) is funding our research project to lay the groundwork for a residential commissioning industry in California. The vision is that this industry will focus on providing end-use energy and non-energy performance assurances for new and existing houses.

To accomplish the goals of this 30 month-long project, which began in September 1999, scientific research methods are being used, with oversight by industry stakeholders and the CEC. These methods include field data collection, laboratory measurements, simulation, and analysis of existing and newly acquired information. We have already completed and published a literature review of existing information on commissioning. We are now midway through our study of metrics, diagnostics, and norms to ascertain what potential benefits one can realistically expect from residential commissioning. By the end of this year, we will begin to write one or more commissioning guides to allow non-experts to achieve these benefits. Project results will also be disseminated through various industry meetings and publications.

January 2001

This month, following the draft plan for the potential value analyses that we presented at our December 2000 PAC meeting, we began defining simulation cases and modeling assumptions. Our quantitative analyses will involve modeling whole-house energy performance, using three house types: an existing 1950-1970 non-retrofitted house, a house that meets current California Title 24 requirements, and a house that represents current Building America practice.

We will consider two scenarios for each house in four different California climates. The first scenario is the baseline performance of the house "as found" during the initial audit and diagnostic phase of a "commissioning" visit. A second scenario corresponds to what a contractor could achieve during the "commissioning" visit through tuning and tweaking of the envelope and HVAC systems. For the existing house, we will also consider a third scenario. That scenario corresponds to further retrofit/improvement opportunities that may be identified during the "commissioning" visit, but that would require major efforts beyond the scope of that visit (e.g. installing wall insulation or a replacement cooling system in an existing house).

Modeling assumptions and input data are being developed based on information from the literature that we have reviewed, from the workshop discussions that we hosted at the ACEEE conference in August 2000, and from our field and lab test results. The focus of these efforts is on commissioning issues involving the envelope (insulation and windows), cooling systems, air distribution systems, and ventilation. Because it is

difficult at this time to quantify the benefits of non-energy issues such as combustion safety, indoor air quality, moisture damage, and comfort, we will deal with these areas on a qualitative basis later in the project.

During January, work continued on disseminating project results. Specifically, three papers directly related to this project are being prepared for publication and presentation. One is our paper for the Performance of Exterior Envelopes of Whole Buildings VIII conference, which will be held in Florida during December 2001. The paper is entitled "Residential Commissioning to Assess Envelope and HVAC System Performance". The paper will describe practical diagnostics that can be used now to commission envelope and HVAC system performance. In particular, it will discuss the accuracy and usability of available diagnostics, based on recent laboratory work and field studies. It will also describe areas in need of research and development, such as practical field diagnostics for envelope thermal conductance and combustion safety.

A second paper that we are preparing is about refrigerant charge testing. It is entitled "An Evaluation of Refrigerant Charge Diagnostics for Commissioning Residential Cooling Systems". The paper will describe the available diagnostic technologies, their accuracy, their utility for contractors, and the barriers to using them. It will include results from our laboratory and field tests last fall. We intend to present this paper at an ASHRAE symposium on refrigerant charge tests, which we are organizing for Honolulu during June 2002. ASHRAE TC 6.3 "Central Forced Air Heating and Cooling Systems" and TC 7.6 "Unitary and Room Air Conditioners and Heat Pumps" have expressed their willingness to cosponsor a symposium on this topic.

The third paper that we are preparing is about the accuracy of flow capture hoods. It is entitled "Evaluation of Flow Hood Measurements for Residential Register Flows". The paper will describe the various flow hood technologies that are available, their accuracy as a function of flow entry conditions, and solutions to current flow measurement problems. It will include the results of our laboratory and field tests last fall. We intend to present this paper at an ASHRAE symposium on airflow measurements, which we are organizing also for Honolulu during June 2002. ASHRAE TC 1.2 "Instruments and Measurements", TC 6.3 "Central Forced Air Heating and Cooling Systems", and TC 9.9 "Building Commissioning" have expressed their willingness to cosponsor a symposium on this topic.

An indirectly related white paper that we are preparing as part of an Environmental Energy Technologies Division collaborative effort describes commissioning issues related to reducing the peak energy demand of new and existing houses. It is entitled "Demand-Responsive Building Systems as a Resource for Electricity Reliability". The paper describes several strategies and technologies to reduce peak demand, including the primary component in California buildings: residential cooling. It suggests that cooling-related demand can be greatly reduced by installing lower capacity cooling

systems, made possible by performing sizing calculations, by reductions in building and system loads (e.g. better windows, ducts, and indoor temperature control), and by commissioning. Other technologies described include the use of electronically commutated (brushless DC) motors for air-handler fans and thermostatic-expansion-valve (TXV) refrigerant controls. The paper also defines related short-term and long-term research needs.

As a project deliverable, we submitted our fifth quarterly status report to the CEC in January for the period October through December 2000.

C. Residential Distribution and HVAC Systems

Thermal Distribution System Figures of Merit
Sponsor(s): DOE, CIEE
Collaborator(s): None

Background
Forced air thermal distribution systems in residences typically lose about 30% of the energy they consume. Because this is a large fraction of the energy consumed by the HVAC system, it is important to be able to provide good estimates of thermal distribution system efficiency. To accomplish this we are developing an ASHRAE Standard to determine the distribution system efficiency of forced air (and hydronic and electric) systems. Also, we have developed sophisticated forced air distribution system computer simulations that are being used to identify potential duct system improvements. These figures of merit are already being used by several authorities (e.g. California Energy Commission and Environmental Protection Agency).

January 2001
We are continuing our technical analyses (with a view to updating our thermal distribution web page) of the effects of duct insulation on duct system performance. In addition, we have begun to look at using the draft ASHRAE Standard 152P calculation method to examine the interactions between multiple speed/capacity equipment and their thermal distribution systems. Specifically we are investigating the reductions in duct system efficiency when system air flows and capacities are reduced, and how this decrease in duct efficiency may offset increases in part-load equipment performance.

A draft report on the DeltaQ duct leakage test method was completed this month. The report includes a technical derivation of the test method, test protocols, summaries of all the field tests to date and uncertainty analyses. This will become part of the final report for the PG&E/CIEE project and was included with supporting documentation for the next draft of the ASTM Duct Leakage standard. We completed a new draft of this standard and submitted it to ASTM this month (it will be balloted in February).

Most of the longevity testing of duct sealants has been completed. Plans were made this month regarding future longevity testing. The consensus is that we still need to test some common duct connections: duct board splitter boxes and round-to-round sheet metal with three wraps of cloth duct tape. A list of proposed samples was prepared and we are currently waiting for the samples to arrive for testing. A new draft of the ASTM Duct Sealant Longevity standard was completed this month and submitted to ASTM.

Iain Walker, Mark Modera and Craig Wray attended many ASHRAE Technical and Standards committee meetings during the ASHRAE Winter meeting in Atlanta. Significant progress was made on proposed ASHRAE 152P (Efficiency of Thermal Distribution Systems) and a second public review draft has been prepared. All the comments received for both the official public review and unofficial comments made to the committee have been satisfied. It is likely that after this standard is published a new committee will be formed to revise the standard as our level of knowledge regarding thermal distribution system performance increases. We have also begun the task of organizing all the documents that have been prepared during the development of this standard. This includes meeting minutes, all previous drafts and the many technical notes we have prepared over the last six years. We are coordinating this effort with John Andrews of Brookhaven National Laboratory.

Distribution System Measurements
Sponsor(s): CIEE, DOE
Collaborator(s): Richard Heath & Associates, CA State University-Chico

Background
Estimates of residential HVAC system performance require measurements of several characteristic parameters. We are writing standard test procedures (through ASHRAE and ASTM) for the building industry to use. This includes development of new test procedures (e.g., the DeltaQ test for residential duct leakage) and evaluation and improvement of existing procedures. Both field and laboratory testing are being used to identify key aspects of distribution system performance so that these systems can be improved in both new construction and retrofits of existing buildings. The field measurements give a baseline for estimating peak demand and energy consumption. The laboratory measurements allow development of test procedures and equipment under controlled conditions.

January 2001
We are continuing to analyze the duct leakage test results from the 100 house field survey and evaluating alternative data analysis procedures for the DeltaQ tests. This month we looked at removing the requirement to measure plenum pressures from the test procedure. Instead, it is possible to determine the duct pressures used in the DeltaQ test calculations from the test data itself. So far, this method shows great

promise and if further testing shows that this method is sufficiently robust it will result in the DeltaQ test becoming even faster and simpler to perform.

A research plan was developed this month for field testing of a house in Fresno, CA. The measurements will consist of short term diagnostics to characterize the building and its HVAC equipment as well as installing a data acquisition system for longer term testing. This house will be continuously monitored for several weeks to determine duct system losses due to continuous air handler fan operation. In addition, the individual room-by-room measurements of air temperature and delivered energy (at each register) will be used to evaluate how well the thermal distribution system serves individual rooms. Both of these issues will potentially be included in future versions of ASHRAE Standard 152P.

The laboratory testing of coil fouling continued this month together with development of some simplified analytical models of deposition. Jeffrey Seigel has submitted a proposal to UCEI proposal to fund further coil fouling experimental work. At the AHR expo at the winter ASHRAE meeting in Atlanta there were about 10 companies selling coil cleaning products. There are many products available but they are either acids, bases, foams, or coatings. One product mixes acids and bases together to give you "the best of both worlds". That sort of misstating of scientific principles seems to be common in the industry. We do not have plans to use any of these coil cleaning products, but we may perform future evaluation work. An alternative experimental procedure that allows the leading edge of the coil to be extracted separately was tested with limited success. Other changes to the experiment include increasing the rate of desorption of fluorescein by heating the buffer solution and using ultrasonic methods. These changes are still at the feasibility level.

Jeffrey Siegel has started work on two papers - a paper for the UEF conference in July and also for ASHRAE IAQ in November. The first is a general overview of the fouling question and the results so far, the second focuses on biological molecules.

Innovative Duct Technology
Sponsor(s): DOE
Collaborator(s): PEG

Background
This DOE STTR is developing a new forced air duct system that uses simple snap together fittings that eliminate duct leakage and many duct system installation problems. Our contribution to this work is to perform field and laboratory testing of the new duct assemblies and to provide commentary and assistance in development of the final design.

January 2001

We are working with PEG to have new prototypes constructed for testing.

D. Commercial Distribution and HVAC Systems

Performance Characterization of Thermal Energy Distribution Systems in Commercial Buildings
Sponsor(s): DOE-EE, CEC
Collaborator(s): None

Background
The DOE project goal is to obtain the knowledge about system performance of thermal distribution systems in light commercial buildings in non-sunbelt regions, i.e., outside of California. This is in companion with the CEC-funded project on the metrics development for the performance characterization of commercial thermal-energy-distribution systems. The objective of the CEC-funded project is to create useful scientific data and test methods to facilitate better design and evaluation of the energy and environmental performance of thermal distribution systems within light commercial buildings (floor area between 2,000-10,000 ft2) and large commercial buildings (floor area over 10,000 ft2).

January 2001
This month, we completed the draft of the outline of proposed metrics and diagnostics methods for characterizing performance of thermal energy distribution systems. We also developed a preliminary test plan on the field characterization of commercial duct systems, including those outside of California. We targeted Wisconsin as our primary region to conduct field tests in light commercial buildings because we have relatively good contacts that we could count on in providing leads and assistance in identifying suitable buildings. The communication with Wisconsin Energy Center was undergoing and we expected to obtain relevant building information in February. Our proposed metrics and diagnostics outlines and the preliminary test plan were submitted to the Project Advisory Committee (PAC) for reviews, and we expected to hear comments from PAC members by the end of March, which would be considered and incorporated into revision version. Selected metrics and diagnostics will be used in the field studies.

Development and Testing of Aerosol Sealing Technologies
Sponsor(s): DOE-EE
Collaborator(s): None

Background
This project is developing and evaluating aerosol-based sealing techniques that could be used in large duct systems.

January 2001

This month's effort in continued injection technology development includes search and ordering new types of nozzles that could be used in the compact injector. Using a new nozzle, we tested the compact injector in different ways to explore whether it could create shallow spray patterns while keeping energy uses for the heater at low levels. We were in the process of experimental setup of duct systems for the upcoming laboratory testing on pressure drops in commercial ducts.

Charles de Loisy, a French student, joined our group this month to assist in the commercial projects. He will be here for approximately four months and is expected to do laboratory experiments on compact injector development as well as field test when needed.

OUTSIDE CONTACTS

Craig Wray continued to participate in conference calls on how the LEED-R Green Building Rating System that is now under development can incorporate residential commissioning.

Craig Wray attended the ASHRAE Annual meeting in Atlanta late this month as acting chair and research subcommittee chair of TC 4.3 "Ventilation Requirements and Infiltration". He also attended the TC 4.7 (Energy Calculations), TC 6.3 (Central Forced Air Heating and Cooling Systems), TC 9.9 (Commissioning), and TC 9.12 (Tall Buildings) committee and subcommittee meetings.

Duo Wang and Darryl Dickerhoff provided advice to technical staff at Digital America on how to set up a facility for calibrating flow capture hoods.

M. Modera attended a CEC hearing on new Title 24.

M. Modera met with the new PIER Director and did a presentation on residential and commercial duct systems research.

M. Modera attended the winter ASHRAE meeting.

M. Modera met with Jim Cummings from Florida Solar Energy Center and John Andrews from Brook Haven National Laboratory working on the Brochure for light commercial duct systems.

M. Modera visited GE Corporate Research Department in Albany, New York, to discuss high efficiency fan, the interactions between HVAC unit, duct system and controls. Prepared a research proposal for NETL with GE and Honeywell.

T. Xu contacted people inside/outside the Lab to gather potential building candidates for this year's tests.

INDOOR ENVIRONMENT DEPARTMENT

2. Ventilation and IAQ Control Technologies

W.J. Fisk, A.J. Gadgil, R.G. Sextro, A.T. Hodgson
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A. Ventilation Measurement Methods

Measuring Outside Air Flow in AHUs
Sponsor(s): DOE-EE
Collaborator(s): none

Background
Current ventilation data indicate that there are wide variations in ventilation rates among buildings. In many buildings, minimum ventilation rates are well below or above the rates in applicable standards. These data and our research experience demonstrate that the common methods of measuring and controlling the rate of outside air supply by air handlers are often inadequate. The consequence is poor air quality in some buildings and excessive ventilation rates in other buildings. Starting in the middle of FY 2000, we initiated a new research effort on methods of monitoring and controlling rates of outside air supply by air handling systems. The work plan is broken into five categories:

- Communication with industry (ongoing throughout the project)
- Literature/hardware review and Common Practice Survey
- Controlled rooftop (or laboratory) experimental evaluation of technologies
- Field studies (small effort before and larger effort after controlled experiments)
- Work with a professional organization to develop performance testing protocols

January 2001
Work started on the review of literature on measurements of outside air flow into HVAC systems. A set of 101 papers potentially relevant were identified in computer searches and reviews of conference proceedings. Citations and abstracts were entered into a database.

B. VOC Sources, Emissions, and Controls

Modeling Emissions of VOCs from Indoor Materials
Sponsor(s): DOE-EE
Collaborator(s): Virginia Tech

Background

Al Hodgson is working in collaboration with professor John Little and graduate students Steve Cox and Deept Kumar of Virginia Tech (VT), Blacksburg, VA to produce mechanistic models that describe the emissions of volatile organic compounds (VOCs) from various solid materials used in buildings. The primary objectives of this research are to better understand and to be able to predict the impact of VOC sources and sinks in the indoor environment. An ancillary goal is to create a less-expensive and superior alternative to emissions testing in environmental chambers for estimating VOC emission rates from building materials. This effort has recently resulted in the development and validation of a physical model for predicting the rate at which VOCs are emitted from vinyl flooring, an exemplary solid-phase material. The key model parameters are the initial concentration of a VOC in the material phase, the VOC material/air partition coefficient and the VOC material-phase diffusion coefficient. These parameters are independently measured using novel methods developed as part of this project. The research collaboration is now attempting to extend the physical model to predict VOC emissions for simple bi-layered materials.

January 2001

Final revisions to the manuscript, "Modeling the Reversible Sink Effect in Response to Transient Contaminant Sources," were completed. The manuscript was submitted to *Indoor Air*. The manuscript, "Predicting the Emission Rate of Volatile Organic Compounds from Vinyl Flooring," was sent out for internal review. Work continued on the modification of the diffusion model to incorporate an initial, non-uniform material-phase VOC concentration.

Impacts of Ventilation Rate on VOC Concentrations and Emission Rates

Sponsor(s): DOE-EE

Collaborator(s): U.C. Berkeley, Center for the Built Environment

Background

A ventilation-rate intervention study (section 3A) is being conducted to quantify the relationships of worker performance in a call center with ventilation rate and air temperature. The three-month study period was concluded in October. The building's air handling systems were operated at three constant outside-air supply rates. The minimum rate corresponded to applicable code requirements. Ventilation rates were periodically changed over 12 weeks. The schedule incorporated both weekly and daily adjustments of the outside air damper settings. Building temperatures, relative humidities, CO_2 concentrations, and airflow rates in the air handling systems were monitored and recorded. The research team is using the opportunity provided by this intervention study to quantify the effects of building ventilation rate on the concentrations and source strengths of VOCs, including formaldehyde. Air samples for VOCs were collected from outdoor air and the four building air returns on a single mid-week day during seven weeks. The air samples were qualitatively analyzed to identify the predominant compounds present in the building. A suite of 50 compounds was

quantitatively analyzed. Measured airflow rates are being used to calculate VOC emission rates for the four air handler zones.

January 2001
Plans were developed to use principal components analysis on subsets of the target VOCs. The objective is to identify groups of compounds with common sources such bioeffluents, cleaning products, building materials and motor vehicle emissions. We will then explore temporal and spatial patterns and the effect of ventilation rate on VOC concentrations by source category.

Comfort and Health-Based Guidelines for Indoor Concentrations and Material Emissions of VOCs
Sponsor(s): DOE-EE
Collaborator(s): Building Ecology Research Group, Health Effects Institute

Background
The overall goal of this project is to develop a methodology for establishing comfort and health-based guidelines for indoor concentrations and material emissions of VOCs. Hal Levin of the Building Ecology Research Group, Santa Cruz, CA and J. Ten Brinke of the Health Effects Institute, Cambridge, MA, are collaborating with A. Hodgson on this effort. A database has been developed that contains approximately 90 individual VOCs spanning a broad range of volatility and chemical functionality. Most of these compounds have been detected in North American houses and office buildings. Available data for the 90 compounds on occupational inhalation exposure guidelines, sensory irritation measured by mouse bioassay, odor thresholds, and chronic reference exposure levels established by the State of California have been summarized from the literature and incorporated into the database. A methodology for evaluating the potential for a compound to elicit a comfort or health-based response among building occupants is currently being evaluated.

January 2001
More literature on sensory irritancy and quantitative structure activity relationships was obtained and reviewed. We initiated an extensive redraft of the manuscript originally titled, "An Ordered Relative Irritancy Scale for Volatile Organic Compounds in Indoor Air."

Joint Research and Demo Project on Energy Efficient and Healthy Homes
Sponsor(s): DOE-EE
Collaborator(s): Florida Solar Energy Center

Background
A primary objective of this research is to determine the sources and entry pathways of the most abundant and persistent VOCs in new houses, including houses with energy-

efficient features. A. Hodgson, in collaboration with Subrato Chandra and David Beal of the Florida Solar Energy Center (FSEC), Cocoa, FL, is currently conducting a field and laboratory study to identify and quantify the sources of terpene hydrocarbons, formaldehyde, other aldehydes and carboxylic acids in a new manufactured house. The house is located in Florida and is used daily as a sales model. The manufacturer supplied a detailed list of all of the materials used in construction of the house. Specimens of the major materials were obtained from the production facility. Laboratory chamber tests were conducted with these materials to measure the emission rates of the target VOCs. These emission rates were used with the material quantities to estimate whole-house emission rates. The predicted emission rates were compared to emission rates calculated from the measured ventilation rates and the concentrations of VOCs in the house approximately four months after its completion. For 11 of 14 predominant compounds, the predicted concentrations agreed within a factor of two.

January 2001
We have started to evaluate the effectiveness of liquid applied vapor barriers for reducing the emissions of aldehydes and other VOCs from plywood subfloors under carpet systems. Product literature and specifications for a variety of water-based sealers were reviewed. Several products including polyurethane finishes were selected for evaluation and were purchased.

C. Ventilation and Indoor Air Quality Studies

Assessment of Particle Control Technologies
Sponsor(s): DOE-EE
Collaborator(s): Helsinki University of Technology

Background
The objectives of this effort are to quantify the reductions in indoor concentrations of particles, from various sources, that result when a variety of air cleaning measures are employed, and to characterize the associated energy costs and total costs. This work is based on analyses of existing data and modeling. The sources of particles considered are outdoor air (fine mode), dust mites, cats, environmental tobacco smoke, and droplet nuclei from coughs and sneezes. The particle air cleaning options include filtration, with various filter efficiencies, and electronic air cleaning. We are evaluating air-cleaning equipment installed within HVAC systems and stand-alone devices.

January 2001
Work continued on the draft paper. The introduction and parts of the methodology section were drafted. A few additional calculations were performed. Various means of graphically displaying the extensive results were employed, a format, and developed most of the charts were prepared.

Task Ventilation Optimization
Sponsor(s): DOE-EE
Collaborator(s): none

Background
In prior years, we have investigated the ability of several task ventilation systems to provide better ventilation, and reduced pollutant levels, at the breathing zone, relative to conventional ventilation systems with well-mixed indoor air. The results of the most recent set of experiments were quite promising. All of the commercially available task ventilation systems have been designed to provide local control of thermal comfort. Improved ventilation at the breathing zone has been an incidental feature of these systems. Starting in the second half of FY2000, we initiated experiments and modeling to optimize ventilation performance. Rather than evaluate commercial products that have not been optimized for ventilation performance, we will design and evaluate new technologies for supplying air near the occupant. As of the end of FY2000, an initial set of parametric studies had been completed to provide qualitative visual images of the airflow patterns between the task ventilation system's air outlet and the breathing zone of a heated mannequin. We also started developing the software for computation fluid dynamics (CFD) modeling of these systems. A post doctoral fellow, Seung Min Lee, started working on this effort during September 2000.

January 2001
Controls for power supply the new thermal mannequin were completed. The multipoint sampling system for the new tracer gas mass spectrometer was tested and control parameters adjusted to obtain good performance. It appears that 8 seconds between samples from different locations is sufficient. Some pilot studies were performed to test the experimental systems. A flow straightener was ordered to make the flow of the task ventilation supply jet laminar.

HyPak Project
Sponsor(s): Davis Energy Group
Collaborator(s): LBNL Building Technologies Department, Davis Energy Group, Des Champs Laboratories, Arthur D. Little

Background:
The Davis Energy Group as prime contractor received an award from NETL to develop an Hydronic Packaged Rooftop Unit (HyPak) that replaces conventional rooftop packaged units but saves energy and improves indoor air quality. The Hypak is designed primarily for climates with a low or moderate humidity. The IED's role in this project is to devise the technology for real-time integrated measurements of the rate of outside air supply, to select the filtration option, and to contribute to a field study of the units IAQ performance.

January 2001
This project started within IED at the end of January.

D. Indoor Environmental Quality and Energy Efficiency in Relocatable Classrooms

Improving IAQ and Saving Energy in Relocatable Classrooms
Sponsor(s): California Energy Commission
Collaborator(s): Davis Energy Group, Pacific Gas and Electric Company

Background
In this study, Element 6 of the California Energy Commission (CEC) funded High Performance Commercial Buildings Systems Program, we will investigate and demonstrate how the application of building science and ventilation engineering can lead to simultaneous building energy savings and indoor environmental quality performance improvements. This project focuses on developing and testing a concept for high-performance relocatable classrooms (RCs). RCs, otherwise known as "School Portables," or "Modular Classrooms," are very common in California. RCs provide school districts with quick and convenient means of adding or replacing classrooms. RCs can be moved around, reducing unnecessary classroom construction. Currently the State of California mandates that at least 20% of new classrooms be RCs.

In this project we will evaluate the benefits of a novel building ventilation system and also of selecting construction materials that emit fewer indoor pollutants. We will construct and study three or four RCs sited in California school districts. One project will test a high-performance ventilation and air conditioning system, the Indirect-Direct Evaporative Cooler (IDEC), suitable for warm dry climate zones of California. In these climates, IDEC offers potential cooling energy savings of about 70% compared to the standard (10 SEER) air conditioner used in RCs. In addition to energy savings the IEDC provides a continuous flow of outside air which will improve the indoor air quality of the RCs. A second project will focus on identifying RC materials that are VOC sources through chamber measurements in RCs. Two RCs tested in the field will be constructed using materials selected for lower VOC emissions. The project will also include an effort to develop, test, and refine computer models of RC energy performance in California. Data from the field study will be used to validate the computer simulations and upgrade inputs to the model. Energy and cost-benefit projections will be made for different California climate zones.

January 2001
Progress was made in all planned activities. Two final selections were made for the school districts (SD) that will participate in the RC field study. One SD is in the California San Joaquin Valley and the second is in the South Bay Area. These sites represent a range of California climate characteristics from high cooling/moderate heating to moderate cooling/light heating. These sites also represent geographic areas with extremely large annual school population increases.

A single RC manufacturer was selected from the three that expressed a desire to be involved in the project. The selected manufacturer operates in Northern California and has longstanding business relationships with both of the selected SDs.

Initial classroom specifications have been collected from the SD architects, and LBNL design modification has commenced.

We visited the manufacturer and obtained specimens of the major materials being used inside standard classrooms. These materials include fiberglass insulation, acoustical ceiling panels, vinyl covered tackable wall panels, carpets and adhesives. In addition, we have contacted a number of manufacturers of materials that might be used as substitutes for the standard materials. Specimens of a number of these alternative materials have been obtained. We have initiated small-scale chamber studies to determine the composition of VOCs and the emission rates of formaldehyde and VOCs of concern from the standard and alternative materials. This information along with performance and cost parameters will be used to select suitable alternative materials for use in the modified classrooms to be constructed later this year.

Plans for instrumentation selection and monitoring strategy for the field study were ongoing. An energy efficient gas-powered hydronic RC heating system to accompany the IDEC cooling system was designed and testing plans were initiated.

Development of DOE2 input files for the statewide energy simulations and cost-benefit projections continued.

E. Airflow and Pollutant Dynamics in Buildings

Particle Deposition to Indoor Surfaces
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley, Dept. of Civil and Environmental Engineering

Background
Inhalation exposure to airborne particles can have adverse health effects. One fate for particles in indoors is deposition onto surfaces. Clearly, this process alters the likelihood of human exposure, since a deposited particle cannot be inhaled unless re-suspended. Knowledge of the rates of particle deposition onto indoor surfaces and the factors governing those rates is therefore important.

January 2001
There was no activity to report for January.

Particle Deposition in Ductwork
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering

Background

The effort under this part of the project is aimed at developing a computational predictive ability for dispersion of gases and aerosols in large indoor spaces. Such a predictive capability will allow development of exit strategies, as well as containment strategies for an unexpected pollutant release in an indoor large space. We are also interested in obtaining an improved understanding of pollutant dispersion in large indoor spaces to reduce occupant exposures under a variety of scenarios.

January 2001

M. Sippola has constructed a re-circulating duct in which to perform experiments. The duct is galvanized steel with a 6 inch, square cross-section. Experimental concentrations of 2.5 μm particles were measured to be 8 times higher in the re-circulating duct than in the previous single-pass duct. Such higher concentrations will allow for both shorter experimental times and higher quality experimental data. Two efforts to conduct experiments have ended prematurely due to a malfunctioning of the monodisperse aerosol generator.

Particle Penetration through Building Cracks

Sponsor(s): DOE-CBNP, LLNL

Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering

Background

The goal of the particle penetration through building cracks investigation is to explore the extent to which particles in infiltrating air remain airborn as the air passes through the building envelope. The work started with modeling, and now includes experiments to validate the predictions. We have finished the idealized crack experiments and will embark on realistic building cracks soon. These results are expected to help us gain insight on the protection of building shell might offer, especially for air leakage dominated buildings.

January 2001

D. Liu performed field measurements of particle penetration factors in a single-family residence in Fresno. The house was well-mixed by fans. Particle measurement instruments were configured to obtain indoor and outdoor particle concentrations. A blower door was used to alternately pressurize and depressurization the house. During pressurization, all particles enter through the fan, making deposition the dominant loss mechanism indoors. During the depressurization process, ambient particles penetrate into the house through leaks in the building shell and losses during penetration may also be an important loss mechanism. By comparing results from pressurization and depressurization, it is expected that particle penetration loss can be determined. Data analysis is currently underway.

Multizone Simulation and Model Development

Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering, Dept. of Architecture

Background
This task seeks to develop and implement models for pollutant transport in buildings. This includes coupling the COMIS multizone airflow program with the MIAQ4 aerosol dynamics model. The model development effort aims to improve our capabilities for predicting gas and aerosol transport in heterogeneous multi-room indoor environments. The models have two major applications: (1) as tools used directly to predict airflow and pollutant transport in buildings; and (2) as testbeds to check our understanding of the physical processes that explain experimental data on pollutant transport.

January 2001
L. Mora finished the first draft of a paper on the mixing time of a point-source pollutant release due to people standing or walking in a room with weak air flows.

Following reviewers' comments, D. Lorenzetti updated a report titled "Computational Aspects of Nodal Multizone Airflow Systems." The paper, report number LBNL-46949, has been submitted to Building and Environment.

D. Lorenzetti began to revise a paper on the future of the COMIS multizone airflow program, based on reviewers' comments. This paper is intended for internal publication only.

A license agreement with EMPA, on the source code for COMIS v. 3.1, appears to be imminent. The current version meets the requirements of both EMPA and Seth Rosen, our contact in the Technology Transfer Department. He has forwarded the agreement to the LBNL Legal Department for final review.

We made progress towards organizing the 16 month visit to the Air Flow and Pollutant Transport group of Dr. Marc Abadie from University of La Rochelle. Dr. Abadie is expected to arrive here in mid February. Research work of Laurent Mora, a French doctoral student, continues to make progress. We received an exploratory inquiry about LBNL's interest in participating in a workshop on multizone airflow network modeling (e.g., COMIS), to be hosted at U. La Rochelle this coming summer.

Christian Lobscheid, a master's student from the Tech. U. of Berlin, continued to make progress with his research.

Prototypical Building Characterization
Sponsor(s): DOE-CBNP

Collaborator(s): None

Background

This project's goal is to develop building management strategies to reduce occupant exposures to an unexpected release of a toxic aerosol or gas. The release could be indoors or in the building vicinity. Our approach is to develop prototypical model buildings that represent the general building stock and to use them to simulate hypothetical pollutant releases. The concentration predictions will help us understand how pollutants are expected to distribute in a building and how event-specific uncertainties might affect the generalizations. Rules-of-thumb response strategies will be developed based on the model predictions. We are currently developing response strategies for commercial office buildings.

January 2001

We completed the draft of a journal manuscript. The paper has gone through LBNL internal review and will be submitted for publication to the journal Indoor Air.

P. Price is leading the "first responders" group's efforts. They finished and distributed a "beta release" draft of information for first responders to an indoor chemical release. This four-page document describes (with illustrations) factors that carry contamination through a building. Different types of building ventilation systems are described, and their influence on the flow of contamination is discussed. The draft has been distributed to building experts, and also to the LBNL and City of Berkeley fire chiefs, for comment. A final version that incorporates their comments is anticipated in early March.

Air Flow and Pollutant Dispersion in a Large Room

Sponsor(s): DOE-CBNP, LLNL

Collaborator(s): None

Background

We are using a combination of computational fluid dynamics (CFD) modeling and experimental work to advance CFD models for use in buildings and to help us to develop a simpler "lumped parameter" model for air flow and pollutant dispersion in a single, large room, *e.g.*, an auditorium, to incorporate into COMIS. This work also involves a collaboration with scientists in France who are developing CFD models.

January 2001

E. Finlayson continues work on the Computation Fluid Dynamics model of multiple releases in the Atrium facility model and on other projects investigating air flow around a workstation and into buildings.

M. Fischer supervised a student, E. Wood, analyzing tracer gas dispersion data collected last summer in the Atrium facility. Fischer also prepared and presented the work on tracer gas dispersion as part of a larger division seminar on the interiors project.

F. Service to Professional and Governmental Organizations

ASHRAE
Sponsor(s): DOE-EE
Collaborator(s): none

Background
Bill Fisk serves on ASHRAE's Environmental Health Committee (EHC's), as chairman of the EHC's Research Subcommittee, and on ASHRAE's IAQ'2001 Organizing Committee.

January 2001
Bill Fisk attended the ASHRAE meeting in Atlanta. He chaired the research subcommittee of the Environmental Health Committee (EHC). participated in the EHC Excom and regular meetings, and in the meeting of the organizing committee for ASHRAE's IAQ'2001 conference to be held this November in January.

Indoor Air 2002 Organizing Committee
Sponsor(s): DOE-EE, AIHA, and many other sponsors
Collaborator(s): U.C. Berkeley, California Department of Health Services

Background
The Indoor Air 'xx conference, held every three years, is the largest and most prestigious international indoor air quality conference. Hal Levin, Bill Nazaroff, Bill Fisk, Rich Sextro, and non-LBNL staff are serving on the organizing committee for the Indoor Air 2002 organizing committee, with Hal Levin serving as the Conference President. DOE contributed $30K during FY2000 to the organization of this conference. Support from a large number of sponsors is anticipated.

January 2001
The organizing committee worked on budgets and sponsorship plans, the conference program, and plenary presentations. Organizers of past meetings were consulted. A cooperative arrangement with the International Society of Indoor Air Quality and Climate is being negotiated.

OUTSIDE CONTACTS

January 2001

Bill Fisk met with the EPRI-led group that will developing plans for IAQ research sponsored by the California Energy Commission. He also attended the ASHRAE meeting.

INDOOR ENVIRONMENT DEPARTMENT

3. Healthy Buildings and Productivity Studies

W.J. Fisk
510-486-5910

A. Experimental Healthy Buildings and Productivity Research

Healthy Buildings Intervention Study
Sponsor(s): DOE-EE, NIOSH, EPA
Collaborator(s): NIOSH

Background
LBNL and NIOSH have conducted a blinded-controlled intervention study in an office building to evaluate the effects of enhanced particle filtration systems, improved surface cleaning, and air temperatures on health symptoms. The filtration intervention involved switching on a weekly basis between typical and high efficiency filters on two floors of an office building. On Thursday or Friday afternoon of each week, occupants reported their health symptom intensities for the current day. Extensive environmental measurements were performed throughout the study. After the seven-week filtration intervention study, a surface cleaning intervention, consisting of special intensive vacuuming of floors and chairs, was performed on one floor with the occupants of the second floor serving as the control group. A third "natural experiment" occurred throughout the study due to natural temporal variations in indoor air temperatures. A short paper on the filtration intervention was published in FY2000.

January 2001
The full-length journal article describing the health-related findings of the particle intervention and time varying indoor air temperatures was completed and submitted for publications. A summary of findings follow: (1) Enhanced filtration, which reduced concentrations of the smallest airborne particles by 94%, was not associated with less severe symptoms, but three performance-related mental states improved; e.g., confusion scale decreased, relative to its mean, -3.7% (95% confidence interval (CI) = -6.5%, -0.9%). Also, most environmental dissatisfaction variables decreased; e.g., stuffy air, -5.3% (95% CI = -10.3, -0.4%). Lower temperatures even within the comfort range were associated with large improvement in most outcomes; e.g., per 1^{o}C decrease, chest tightness decreased -23.4% (95% CI = -38.1%, -8.7%). Thus, removal of small airborne particles was associated with meaningful improvements in performance-related mental states and some environmental dissatisfaction measures, but not in symptoms.

The citation is:

MJ Mendell, WJ Fisk, MR Petersen, CJ Hines, MX Dong, D Faulkner, JA Deddens, AM Ruder, D Sullivan, MF Boeniger (2001) Experimentally Enhanced

Particle Filtration, Observed Temperature Variation, and Changes in Questionnaire-Based Outcomes among Office Workers. Submitted to Epidemiology.

Ventilation Rate Intervention Study
Sponsor(s): DOE-EE
Collaborator(s): Center for the Built Environment

Background
In this study, we are quantifying the relationships of worker performance in a call center with building ventilation rate and air temperature. Worker performance is being determined from the automatically-recorded telephone call data at three relatively constant outside-air ventilation rates, and also with the economizer system operating. The minimum ventilation rate corresponds to applicable code requirements. Periods of steady ventilation rates range from one week to one day. Indoor air temperatures and building occupancy fluctuate naturally. Temperatures, humidifies, carbon dioxide concentrations, and VOC concentrations are being monitored.

January 2001
Scanning, checking, and cleaning of productivity data was completed and code to read the various files and set up the input for a least squares analysis is being written. There are some glitches in the space temperature trends that seem unusual.

B. Literature Reviews and Assessments

Association of HVAC Type and Features with SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): Helsinki University of Technology

Background
Cross-sectional studies from around the world have investigated the relationship of HVAC system type in commercial buildings with occupant health symptoms. LBNL and the Helsinki University of Technology are collaborating on a critical review of the literature. This document will summarize the findings of studies that satisfy study quality criteria and review the evidence supporting or refuting the hypothesized explanations for the observed associations.

January 2001
The paper on the association of HVAC type with SBS symptoms was completed and submitted to the journal Indoor Air. This paper provides a review and synthesis of current knowledge about the associations of ventilation system types in office buildings with sick building syndrome symptoms and discusses potential explanations for the associations. Relative to natural ventilation, air conditioning, with or without

humidification, was consistently associated with a statistically significant increase in the prevalence of one or more SBS symptoms. Prevalences were typically higher by approximately 30% to 200% in the air conditioned buildings. In two of three assessments from a single study, symptom prevalences were also significantly higher in air conditioned buildings than in buildings with simple mechanical ventilation and no humidification. In approximately half of assessments, SBS symptom prevalences were significantly higher in buildings with simple mechanical ventilation than in buildings with natural ventilation. Insufficient information was available for conclusions about the potential increased risk of SBS symptoms with humidification.

A short summary of our prior paper on the association of ventilation rates and CO_2 concentrations with occupant health and productivity was published in the popular IEQ Strategies Newsletter.

Health and Productivity Reviews
Sponsor(s): DOE-EE
Collaborator(s): None

Background
In this area of work, critical reviews are performed to assess the opportunities for health and economic gains from improvements in indoor environmental quality.

January 2001
The review article on opportunities for health and productivity gains was published in a new IAQ handbook. The citation follows:

> Fisk, WJ (2000) Estimates of potential nationwide productivity and health benefits from better indoor environments: an update. Chapter 4 in *Indoor Air Quality Handbook*, eds: J. D. Spengler, J.M. Samet, and J.F McCarthy, McGraw Hill

IAQ and Health in Schools
Sponsor(s): DOE-EE
Collaborator(s): University of Minnesota

Background
In 1999, the IED, working with Bill Angel at the University on Minnesota, completed a report on a broad review of IAQ and associated health problems in schools. A conference article based on this review was presented in FY1999. The FY2001 plans are to complete and submit a journal article based on this work.

January 2001
There was no activity on this topic during January.

C. Analyses of Data from the EPA BASE Study

VOCs and SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): EPA developed the database for these analyses

Background
EPA has collected a large set of data from office buildings, including building characteristics, air pollutant concentrations, and SBS symptom prevalences. We have used statistical models to analyze data from the first set of buildings and learn about the associations of volatile organic compounds with symptoms. The analysis will now be extended, using the data from all 100 buildings.

January 2001
During January we completed data cleaning and processing of the environmental monitoring data within the100 building BASE dataset. These data include VOC (both canister and multisorbant), CO2, CO, temperature, and relative humidity. These data will be used in upcoming multivariate analyses. We commenced cleaning of the demographic and symptom data in the BASE survey dataset. Mike Apte and Kate Steiner met with Kai Shen Liu, Janet Macher, and Feng Tsai of the Indoor Air Branch of the California Department of Health Services (DHS) to discuss potential collaboration and standardization of analyses of BASE study data. DHS is contracted with the USEPA to analyze the BASE Study microbiological data.

Carbon Dioxide and SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): U.S. EPA

Background
For this task, we are using multivariate statistical models to analyze data from the EPA BASE study to investigate the association of indoor carbon dioxide concentrations with SBS symptom prevalences.

January 2001

We continued to prepare the 100 building data set for analyses, as described in the previous section on VOCs and SBS Symptoms.

D. Service To Professional And Governmental Organizations

National Occupational Research Agenda
Sponsor(s): DOE-EE supports time of LBNL staff serving on the National Occupational research Agenda Indoor Environment Team.

Collaborator(s): Broad representation on Committee from government, universities, labor

Background
Bill Fisk is participating in the activities of the National Occupational Research Agenda (NORA) Indoor Environment Team. The objectives of this interdisciplinary team established by NIOSH are to develop a priority research agenda related to IAQ and health in non-industrial occupational buildings, and to foster partnerships and collaborations as needed to implement the research agenda. This multi-disciplinary team is developing a paper on the highest priority research needs related to IAQ and health in non-industrial occupational environments.

January 2001
The NORA IEQ team document was cleared by the NIOSH Office of the Director. Final revisions are underway.

California IAQ Interagency Working Group
Sponsor(s): DOE-EE supports the participation of LBNL staff in these meetings
Collaborator(s): Broad representation from the sponsors and performers of IAQ research in California

Background
The California Interagency Working Group (CIAW) meets quarterly to maintain communication on IAQ activities in California. Mike Apte serves as LBNL's representative.

January 2001
No activity.

OUTSIDE CONTACTS

January 2001
Ms. Mary Anne Volk from the United Technologies Research Center visited to learn about IED research, particularly about health and productivity research.

INDOOR ENVIRONMENT DEPARTMENT

4. EXPOSURE AND RISK RESEARCH

T.E. McKone, W.J. Fisk, A.T. Hodgson, R.G. Sextro
486-6163

A. Environmental Tobacco Smoke Research

Further Characterization of Environmental Tobacco Smoke
Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): None

Background
In this project, led by Rich Sextro, laboratory and field research is being conducted to assess the usefulness of particle-bound components of ETS as tracers for exposure assessment studies.

January 2001
Work continued to work on the project final report. A proposal was submitted to TRDRP for continuation of the project for two more years. The proposal is for a study that would measure ETS tracer behavior in 20 residences.

Vapor-Phase Organics in Environmental Tobacco Smoke
Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): U.C. Berkeley Department of Environmental Engineering

Background
Brett Singer and Al Hodgson are working on this project with assistance from several undergraduate students in the U.C. Berkeley Environmental Engineering Department. The project focuses on quantifying human exposure to vapor-phase organic compounds in ETS under a range of realistic smoking patterns and ventilation rates. Special attention is being paid to sorption processes that can have a large impact on airborne concentrations of semi-volatile organic compounds (SVOCs; *e.g.*, nicotine) both during and long after active smoking periods.

January 2001
We initiated an experiment to measure vapor-phase ETS concentrations in a furnished chamber daily smoking. Ten cigarettes are smoked each evening to simulate the behavior of a working adult who smokes at home only in the evening. Smoking occurs six days per week, always within a four-hour window. Twice per week (on days three and six), a suite of air samples is collected during the four-hour smoking period, a ten-hour post-smoking period (overnight) and a ten-hour background period to complete a 24-hour cycle. Additional VOC samples are collected each day during background

periods. These samples are being analyzed for an extensive list of target VOC, total particulate mass, and aldehydes. The experiment will last at least for weeks and is continuing into February.

B. Performance of Smoking Rooms

Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): California Department of Health Services

Background
The IED and the California Department of Health Services (CDHS) are studying the performance of smoking rooms. Laboratory studies will assess the rate of ETS leakage from a smoking room to the adjoining space as a function of smoking room physical characteristics, door usage, and temperature and pressure differences. A mathematical model of smoking room performance will be developed and model predictions will be compared with measured data. A final phase of the project will assess the accuracy of the model in predicting the performance of smoking rooms located in a small number of office buildings.

January 2001
Measurements of environmental tobacco smoke (ETS) leakage from a smoking room continued. Using the pressure difference between smoking and non-smoking rooms (ΔP), the temperature difference between smoking and non-smoking rooms (ΔT), and rate of door opening as variables, 3 sets of experiments were completed:

1) ΔP = (-5, 0, and 5 Pa), all at ΔT = 0C and 8 door openings/hr
2) ΔP = (-5, 0, and 5 Pa), all at ΔT = -2C and 8 door openings/hr
3) ΔP = (-5, 0, and 5 Pa), all at ΔT = 0C and 13.33 door openings/hr

Temperature gradient does not appear to have a major effect on the smoking room exhaust efficiency or exposure of non-smokers. Increased door frequency has a small effect when the smoking room is not at a positive pressures, as predicted. Even when the smoking room was kept at a lower pressure than the non-smoking room, a measurable amount of ETS ended up in the non-smoking room due to the pumping action of the door.

Analysis of the first nicotine, 3EP, and PM samples allowed comparison of the various tracers of ETS. All tracers follow the same qualitative trends. However, the exposure of non-smokers is highest when measured with SF6, with slightly lower values for PM and 3EP, and nicotine substantially lower.

C. The California Exposure Modeling Research Center

A Multi-Domain Framework for Integrating Models and Measurements of Multimedia Environmental Contaminants
Sponsor(s): U.S. EPA National Exposure Research Laboratory
Collaborator(s): U.C. Berkeley, Stanford University

Background
Tom McKone, Deborah Bennett, Neil Klepeis, Randy Maddalena, William Riley, and Agnes Bodnar are working on this project at LBNL; Wayne Ott and Paul Switzer are working on this project at Stanford University; and William Nazaroff, Katharine Hammond, and Michael Tarter participate through U.C. Berkeley.

The goal of this project is to develop and apply models to improve the process of exposure assessment in two ways. First is to provide a more complete picture of how humans are exposed to a number of important pollutants. Second is to determine the level of precision that is feasible for quantifying human exposure to these pollutants. These efforts are being organized around two research components: (1) an indoor/outdoor model for total human exposure to particulate matter (PM); and (2) development and evaluation of source-to-dose models for persistent pollutants. These two components include a number of research areas.

January 2001
M. Sohn and T. McKone continued their collaboration with Jerry Blancato, Marc Rigas, and Fred Powers of U.S. EPA, Las Vegas to use dose biomarkers to reconstruct pollutant exposures. In January, we worked on methods for analyzing biomarker data. We also identified the types of data routinely gathered in exposure surveys that can improve exposure reconstruction for various classes of chemicals. Our approach is to make use of non-specific (or synthetic) chemical properties to determine how simple physiologically based pharmacokinetic models link to exposure history. Synthetic chemical data help us test our approach and tools. Chloroform-like semi-volatile compounds are under consideration as candidates for a demonstration with "real" chemicals.

D. Bennett, T. McKone and M. Margni completed the manuscript entitled "Dose Fraction for Multimedia Pollutants: A Tool for Life Cycle Analysis and Comparative Risk Assessment." It was submitted to the journal *Risk Analysis*. Dose Fraction is a measure of exposure in regional multimedia models.

R. Maddalena reviewed and revised the December version of the CalTOX technical support document. D. Bennett completed a draft of the addendum to the exposure manual for CalTOX. This addendum includes all changes that were made to the exposure component of CalTOX during the last six months. Kirsten Enoch, an LBNL research associate from the University of San Francisco, completed a draft of the CalTOX user's guide. This guide reflects the changes that were made to the operation

of the model over the last six months. The user's guide is being reviewed and edited by T. McKone.

W. Riley, T. McKone, and W. Nazaroff completed a final draft of the paper entitled "Indoor Particulate Matter of Outdoor Origin: The Importance of Size-Dependent Removal Mechanisms". The paper is receiving internal review at LBNL. After internal review and any final revisions, it will be submitted for publication to *Environmental Science and Technology*.

W. Riley continued to work on a dermal uptake model for short contact times by reviewing Malathion uptake data for rats (from U.S. EPA, Las Vegas). We are integrating this new rat data into the model of dermal uptake during short-term exposure events. Riley reviewed the literature to identify other studies that he and T. McKone can use to calibrate the short-term/intermittent-contact model.

As part of his effort to build an activity pattern simulator, N. Klepeis continued to search and evaluate the literature on activity patterns and modeling.

Based on the updated version of the U.S. EPA SHEDS model, R. Maddalena and D. Bennett developed a plan for evaluating the model and for performing various levels of sensitivity and uncertainty analyses on the model.

In an effort to determine what processes need to be included in the indoor fugacity (chemical partitioning) model, D. Bennett reviewed literature on indoor modeling in order to identify other mass-balance studies. From the theory and data available, she developed a set of differential equations to use in our proposed EPA model. This information was sent to the EPA Exposure Laboratory in Las Vegas where Ed Furtow is preparing the program to solve these equations. Bennett also worked on developing mass-transfer coefficients for mass exchange among indoor compartments.

A. Bodnar continued collecting data on source characterization of PAH emissions to the San Francisco Bay Area air shed. These data are being use to relate the emissions of PAHs with potential inhalation and ingestion exposures to the Bay Area population. With assistance from R. Maddalena, she continued an evaluation of plant uptake data generated in U.C. Berkeley exposure chambers.

The paper entitled "The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants," by N. Klepeis, et al., has been finalized for publication in the *Journal of Exposure Analysis and Environmental Epidemiology*. W. Ott and P. Switzer were contributors. This paper presents the first findings to be published in the scientific literature from the U.S. EPA's two-year probability-based survey of the activity patterns of the U.S. population nationwide. Exposure-related questions were obtained from each of 9,386 respondents nationwide.

The NHAPS respondents reported spending an average of 87% of their time in enclosed buildings and 6% of their time in enclosed vehicles.

D. Total Risk Integrated Methodology (TRIM) Project

TRIM.FaTE Project
Sponsor(s): U.S. EPA Office of Air Quality, Planning and Standards
Collaborator(s): Oak Ridge National Laboratory, University of Tennessee, ICF Consulting

Background
Randy Maddalena, Tom McKone, Deborah Bennett, and Agnes Bodnar are working on this project. The Total Risk Integrated Methodology (TRIM) is an EPA project to develop models and data for assessing the multimedia residual health and ecological risk from pollutants released to air sheds. The LBNL team is working on two components of the TRIM project: (1) testing, evaluation, and validation of the TRIM.FaTE module; and (2) development of the TRIM.Expo multimedia, multipathway exposure model.

January 2001
R. Maddalena, D. Bennett, and T. McKone reviewed and prepared comments on parts of the TRIM.FaTE evaluation report. They also participated in TRIM conference calls and responded to e-mail questions about the model-evaluation process.

E. Criteria for Evaluation and Development of Probability Density Functions for a Set of Human Exposure Factors

Exposure Factor Distributions
Sponsor(s): U.S. EPA Office of Emergency and Remedial Response
Collaborator(s): None

Background
Randy Maddalena, Tom McKone, and Agnes Bodnar are working on this project. The Office of Emergency and Remedial Response (OERR) plays a lead role in developing national guidance and planning future activities that support the EPA Superfund Program. The purpose of this project is to develop for OERR methods for scoring the quality, relevance, and reliability of probability density functions.

January 2001
R. Maddalena completed some final evaluation runs for constructing probability density functions (PDFs) using distributions based on both demographic data and information about the characteristics of the target population. Maddalena also

completed a detailed Executive Summary for this project and submitted it for review by the Agency sponsors.

F. Inter-Individual Differences in Metabolism of Carcinogens as a Risk Factor for Breast Cancer
Sponsor(s): U.S. Department of the Army
Collaborator(s): None

Background
The purpose of this project, led by Regine Goth-Goldstein, is to test for possible genetic factors that contribute to breast cancer risk, such as inter-individual variation in the level of enzymes that activate or detoxify environmental carcinogens. Variation in the level and activity of these enzymes can be due to mutations in the DNA sequences of the genes coding for these enzymes (genetic polymorphism) or to modification of gene expression by genetic and environmental factors. We have focused on the cytochrome P450 enzymes CYP1A1 and CYP1B1, both involved in activation of polycyclic aromatic hydrocarbons (PAHs). We are investigating whether the level of expression of these genes in breast tissue represents a risk factor for breast cancer.

January 2001
There were no new research results. We continued to work on a manuscript on *CYP1B* expression as a risk factor for breast cancer.

G. Measurement of Semi-Volatile Organics in Ambient Air

Sponsor(s): U.S. EPA, EPRI, University of Texas, Washington State University
Collaborator(s): U.S. EPA, EPRI, University of Texas, Washington State University, Environment Canada, University of Washington, U.C. Berkeley, U.C. Los Angeles, Desert Research Institute, Restek Corporation, URG Corporation

Background
The objective of this project, led by Lara Gundel, is the development, validation, and application of new measurement methods for the accurate determination of semi-volatile organic pollutants in ambient air. Such species partition between the gas and particle phases in ways that complicate measurement and apportionment efforts. LBNL is contributing to several multi-investigator studies whose overall goal is the characterization of carbonaceous particles across the U.S.

January 2001
Work continued on the final project report to the U.S. EPA and on journal articles regarding the recent validation studies of diffusion-based sampling methods for semi-volatile and particulate organic pollutants. We began to determine the contribution of semi-volatile organic compounds to the large indoor sampling artifacts that have been observed in DOE-funded studies, using thermal analysis.

LBNL used the high-capacity version of its diffusion-based air sampler as part of its participation in characterizing particulate phase semi-volatile organic compounds in the Pacific Northwest. LBNL's participation is now supported as part of a collaborative study with the University of Washington and Washington State University.

LBNL's participation the Texas Air Quality Study 2000 officially began with a new contract with the University of Texas.

H. Traffic Study

Sponsor(s): California EPA, Office of Environmental Health Hazard Assessment (OEHHA)
Collaborator(s): OEHHA

Background

OEHHA is conducting a study of respiratory health of school children (4^{th} and 5^{th} grades) that reside and attend school in several California East Bay Area communities. OEHHA is attempting to determine whether the children's total exposures to traffic-related emissions are related to respiratory symptoms. LBNL is assisting OEHHA with the environmental measurements for the study. Our primary objectives are to identify markers for gasoline and diesel powered vehicle-related pollution and to make field measurements of these gaseous and particulate pollutants both indoors and outdoors at a set of East Bay Elementary schools throughout the remainder of the school year. Brett Singer, Tosh Hotchi and Al Hodgson are conducting this study.

January 2001

We completed the development of an overall sampling plan in collaboration with the OEHHA project managers. We designed the systems for the simultaneous sampling of PM_{10}, $PM_{2.5}$, black carbon, carbon monoxide (CO), nitrogen dioxide/total nitrogen oxides (NO_2/NO_X), and target volatile organic compounds (VOCs). This included the selection and ordering of the following components: sampling pumps, size-selective inlets for particles, CO monitors, passive NO_2/NO_X samplers and passive VOC monitors. The systems incorporate custom-designed battery power sources for operating the pumps over weeklong periods and custom-designed enclosures to protect the equipment at outdoor locations. We began the testing and calibration of some of the sampling equipment. We started to prepare draft protocols for sample collection and analysis. We also visited candidate schools to discuss access issues and to determine the appropriate placement of the equipment.

I. Other Efforts

January 2001

During January the Exposure and Risk Analysis Group held one group meeting on January 26. During this meeting R. Maddalena discussed his evaluation of how default distributions can be used in probabilistic risk assessments.

D. Bennett, M. Margni, T. McKone, W. Nazaroff, and W. Riley from LBNL; John S. Evans from Harvard University; and Kirk Smith from U.C. Berkeley, the Dose Fraction Working Group, continued to work on a manuscript that will define and illustrate the concept of "Dose Fraction."

R. Maddalena prepared a news column on fate and exposure modeling for the Society of Environmental Toxicology and Chemistry (SETAC) newsletter "GLOBE".

Regine Goth-Goldstein submitted two grant proposals to study the health effects of 7*H*-benzo[*c*]fluorene. One was submitted to the California Breast Cancer Research Program and was entitled, "Potential role of 7*H*-benzo[*c*]fluorene in breast cancer." The other was prepared in collaboration with Lara Gundel and was submitted to the Tobacco-Related Disease Research Program. It was entitled, "Benzo[*c*]fluorene, a candidate tobacco smoke carcinogen."

Lara Gundel and collaborators submitted a proposal to the Tobacco-Related Disease Research Program to study the secondary uptake of nicotine by infants. Gundel submitted a pre-proposal on energy efficient air cleaners for semi-volatile organic compounds to the Technology Research Program of DOE. Gundel also submitted a proposal to EPRI to determine the semi-volatile polycyclic aromatic compound benzo(c)fluorene, first in coal tars and later in ambient particulate matter.

Lara Gundel and staff continued to prepare filter-sampling materials for the indoor/outdoor field study in Fresno lead by Nancy Brown of the Environmental Energy Technologies Division at LBNL. Chemical speciation began for particles collected in Fresno in October and December.

OUTSIDE CONTACTS

January 2001

Kathrin Fenner started a three-month stay as a visiting researcher with the Exposure and Risk Analysis Group. Kathrin is from the Laboratory of Chemical Engineering, Swiss Federal Institute of Technology, Zurich, Switzerland, where she is completing her Ph.D. research. Her work involves an approach to extend the concept of persistence to transformation products of environmental chemicals. She has developed methods to describe the additional exposure of the environment that is caused by the presence of transformation products. Kathrin has been working with R. Maddalena and D. Bennett on sensitivity and uncertainty analysis methods for evaluating the joint persistence model.

Larry Goldstein and Michael Van Loy of EPRI visited LBNL to discuss future collaborative work on semi-volatile organic compounds.

INDOOR ENVIRONMENT DEPARTMENT

5. International Energy and Environmental Activities

A.J. Gadgil
510- 486-4651

A. UVWaterworks
Sponsor(s): DOE-EE
Collaborator(s): None

Background
The UVWaterworks system uses ultraviolet (UV) light to treat water contaminated with bacteria, viruses, and Cryptosporidium. The technology, developed at the Lawrence Berkeley National Laboratory, has been licensed to WaterHealth International (http://www.waterhealth.com). DOE has supported limited field trials of the technology in South Africa, as part of DOE's participation in the SA-US-BiNational Commission.

January 2001
Following a massive earthquake (magnitude 7.9) in India on January 26, 2001, there was expression of interest in using UVWaterworks to help meet the drinking water needs of the estimated 600,000 persons rendered homeless by the earthquake. What help can be actually given will be determined in February when logistics and funding becomes clearer.

B. Other Efforts

None.

INDOOR ENVIRONMENT DEPARTMENT

6. Program Support and Administration

W.J. Fisk
510-486-5910

January 2001

IED staff started work on FWPs and FPPs for DOE.

A position was posted for a new full-time administrative assistant for IED.

Bill Fisk and the heads of other EETD research departments met with Mark Ginsburg of DOE on January 12 to discuss a variety of strategic issues.

Input was provided to DOE for a review by the NRC of DOE's research programs

IED staff started submittal of a second monthly report to DOE that provides information for DOE's data base.

7. STATUS OF FY2001 DELIVERABLES FOR DOE/OBT

Deliverable or Milestone	Due Date	Status
TASK 1. ENERGY PERFORMANCE OF BUILDINGS		
Completion of First Public Review of Standard 62.2	11/00	Completed
Preliminary Analysis of Air Leakage Database	1/01	Completed
Status report on Energy Efficiency Ventilation Demonstration Case Study	3/01	
Recommendations regarding future participation of the US in AIVC	5/01	
Second Public Review of Standard 62.2	7/01	
Technical paper on infiltration heat recovery	9/01	
TASK 3. VENTILATION AND IAQ CONTROL TECHNOLOGIES		
Submit paper on comparative assessment of particle air cleaning	11/00	Delayed
Submit journal paper on a new approach for measuring the concentrations of VOCs in vinyl flooring	12/00	Completed
Submit journal paper on validation of a single-layer model to predict emissions rates of VOCs from vinyl flooring	3/01	
Paper on literature review and product and practice survey for measurement and control of outside air supply by HVAC systems	7/01	
Conference paper on methodology for establishing health- and comfort-based criteria for VOC emissions from building materials	9/01	
Paper on task ventilation optimization studies	9/01	
TASK 4. HEALTH BUILDINGS AND PRODUCTIVITY RESEARCH		
Submit paper on IAQ, ventilation, and health in schools	10/00	Completed
Complete data collection in productivity field study	12/00	Completed
Article for ASHRAE Journal or equivalent on ventilation rates and health	6/01	
Paper on analyses of BASE Study data from 100 buildings	7/01	
Draft paper on productivity field study	8/01	
Expanded article on association of symptoms with high-efficiency filtration, temperature, and humidity is accepted for publication	9/01	Submitted
Submit journal article on HVAC and health	9/01	Submitted
TASK 5. ENERGY EFFICIENT FUME HOODS		
Technical paper on design development and test results of high-performance fume hood	6/01	
Article on high-performance fume hood for professional publication	12/01	
Task 6. IAQ Assessments of New Energy-Efficient Housing		
Submit journal paper on sources of formaldehyde and other VOCs in a new manufactured house	9/01	